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Research and Development Plan

GIF Policy and Experts Meeting: Rio de Janeiro
July 9-10, 2002

Generation IV

Topics

- Process used to define R&D
- Overview of R&D phases
- Highlights of R&D recommendations
  - Concept specific
  - Crosscutting
- Next steps

R&D Definition Process

- TWGs first identified technology gaps/issues, focusing on selected systems

Sodium liquid metal-cooled reactor system	(Na LMR)
Very high temperature reactor system	(VHTR)
Supercritical water-cooled reactor system	(SCWR)
Lead or lead/bismuth-cooled cartridge core reactor system	(Pb/Bi Battery)
Gas-cooled fast reactor system	(GFR)
Molten salt reactor system	(MSR)

- Gaps were characterized in terms of
  - Significance to system viability/performance/optimization
  - Magnitude, using "technology readiness scale"
- TWGs defined R&D activities to address gaps
  - R&D characterized in terms of priority, duration, and cost

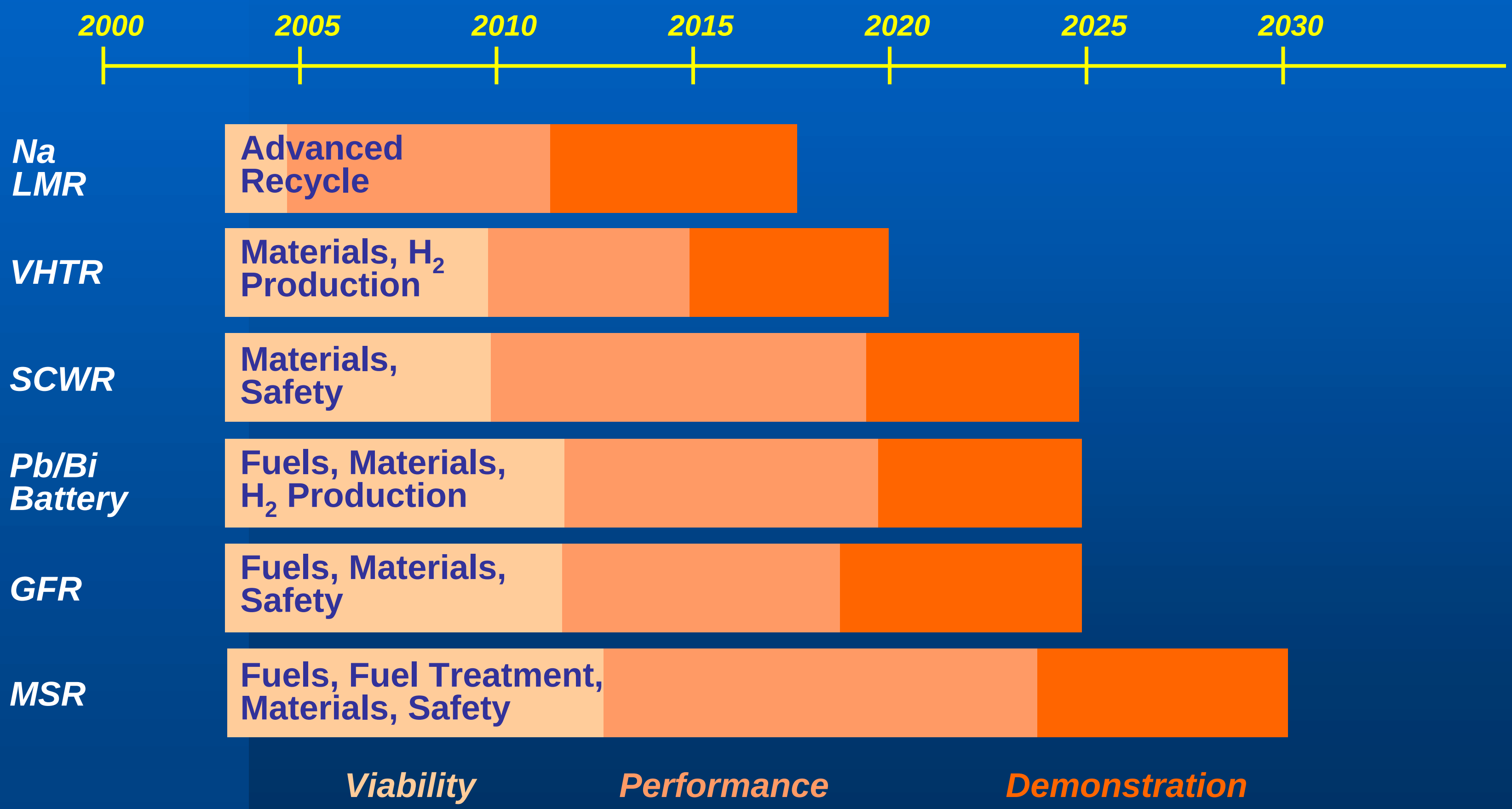
R&D Definition Process, cont'd

- Crosscut groups (CGs) examined
  - Crosscutting technology gaps and R&D
  - Opportunities for R&D common to multiple concepts
- Technology gaps and R&D are documented in R&D Scope reports
  - One report from each TWG and CG
- R&D priorities and time phasing were reviewed by the RIT and WG leaders during the Boston quarterly meeting
- Summaries of R&D recommendations were drafted for the Interim Roadmap

R&D Phases

- *Viability establishment phase*
  - *Prove basic concepts, technologies and processes at relevant conditions*
  - *Identify and resolve potential "show-stoppers"*
  - *Specify most promising technical options*
- *Performance qualification phase, contingent on successful completion of viability R&D*
  - *Verify system capabilities at engineering scale in prototypical conditions*
  - *Develop conceptual design of demonstration system*
- *System evaluation planned at the end of the viability phase*
  - *Verify performance potential relative to goals*
  - *Using advances in evaluation methodology*

Concept Development Phases

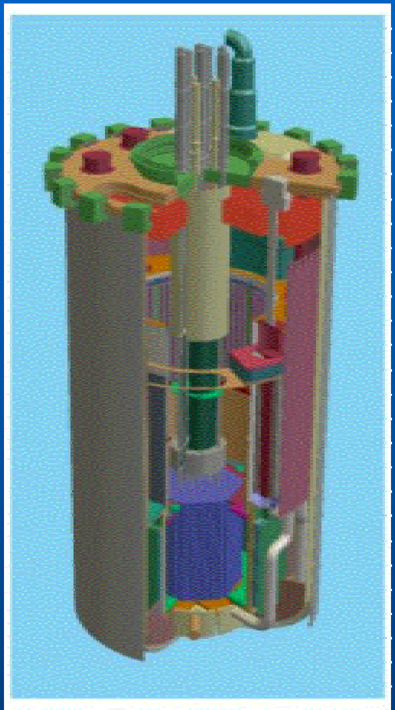


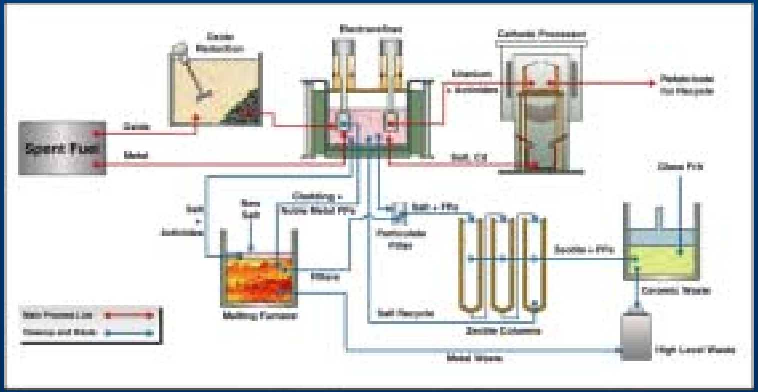
Concept R&D Overview

- Key technology gaps for each system
- Recommended viability R&D activities
- Overview of performance R&D

Sodium LMR: Technology Gaps

- *Fuel cycle technologies for actinide management*
  - *Waste minimization*
  - *Waste form durability*
  - *Proliferation resistance*
- *Reactor technology is comparatively mature; remaining needs include*
  - *Passive safety assurance*
  - *Cost reduction*
  - *Improved in-service maintainability*



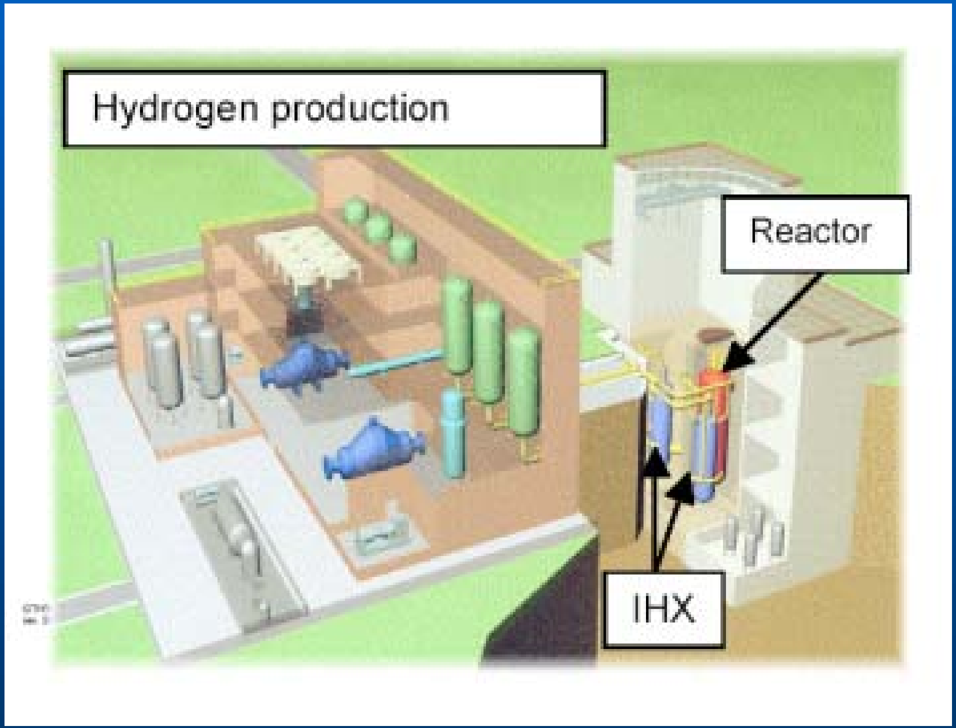


Sodium LMR R&D

- *Engineering development of advanced aqueous technology*
  - *Powdering technology for fuel de-cladding*
  - *Crystallization method for extraction of excess U*
  - *Co-extraction of U/Pu/Np; low-waste recovery of Am and Cm*
  - *Simplified pellet fabrication process*
- *Development and scale-up of pyroprocess technologies*
  - *Head-end reduction of LWR spent fuel to metal*
  - *Recovery of transuranics from metallic fuel*
  - *Waste reduction and waste-form qualification*
- *Fuel development*
  - *Remote fabrication of minor actinide bearing fuels*
  - *Performance of recycled fuel*
- *Improvement of capabilities for in-service inspection and repair*

VHTR: Technology Gaps

- Fuels and materials for increased temperature operation
  - Targeted outlet temperature >950°C
  - Requires extension of technology base of nearer term systems, e.g., coated particle fuels
- System application to hydrogen production
  - Efficient and safe coupling of the reactor and thermo-chemical process plant

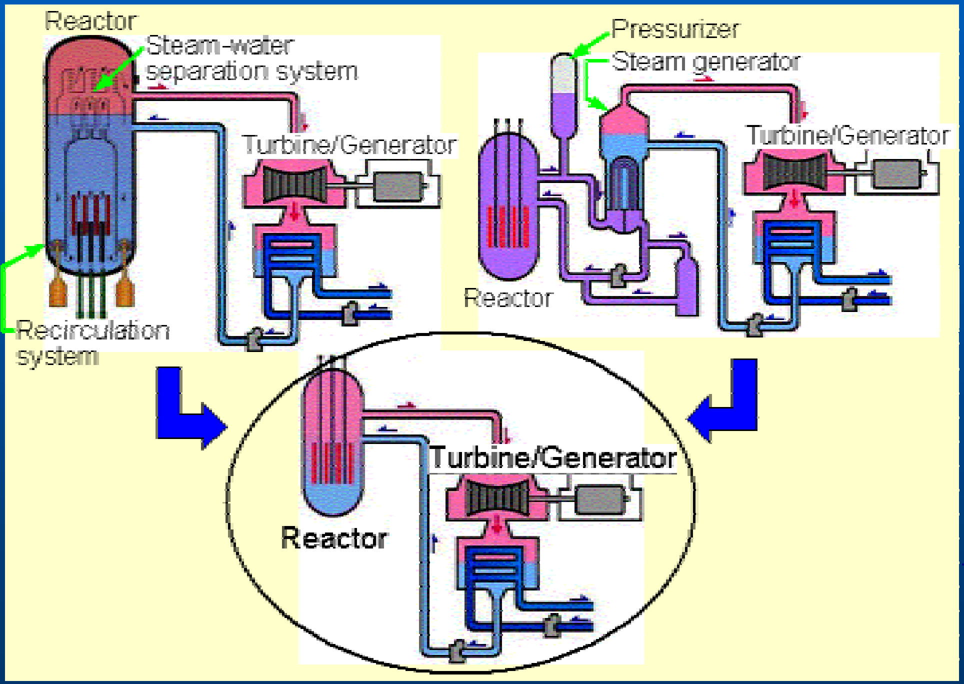


VHTR R&D

- *Fuels for increased operating and transient temperatures*
  - *High temperature coatings (e.g., ZrC)*
  - *Fuel design for reduced temperature rise*
- *High temperature materials development*
  - *Metallic materials for IHX, gas ducts/pipes, isolation valves (e.g., Ni-Cr-W super-alloy)*
  - *Ceramic materials for T >950°C (e.g., C/C composites, super-plastic ceramics)*
- *Development of the reactor interface with the energy conversion system*

SCWR: Technology Gaps

- *Materials for cladding and core structures in supercritical water*
  - *~25 MPa, 500°C coolant outlet temperature*
  - *Requires extension of technology bases from ALWR and supercritical water (SCW) fossil plants*



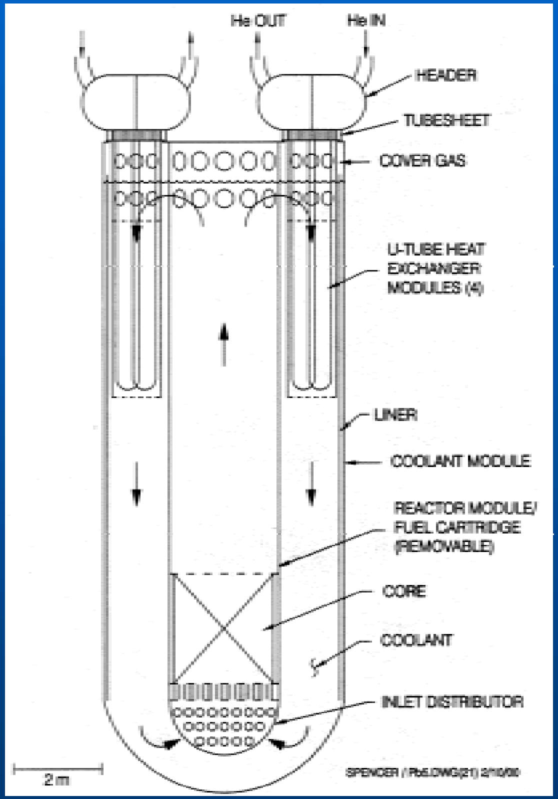
- *Reactor safety*
  - *T/H data*
  - *LOCA progression*
  - *Stability*

SCWR R&D

- *Testing of cladding and structural materials to demonstrate*
  - *Resistance to corrosion and stress corrosion cracking*
    - *For temperatures up to 620°C*
    - *For radiation doses up to 30 dpa (thermal); 150 dpa (fast)*
    - *Accounting for water chemistry and radiolytic decomposition*
  - *Dimensional and micro-structural stability*
  - *Strength, ductility and creep-resistance as a function of irradiation dose and temperature*
- *Safety R&D*
  - *Measurements to reduce uncertainty in SCW transport properties and correlations for heat transfer and fluid flow*
  - *Measurement of LOCA phenomena and adaptation/qualification of computer models*
  - *Verification of ability to prevent and control power-flow instabilities*

Pb/Bi Battery: Technology Gaps

- *Metallic or nitride fuel for ultra long life core*
- *Recycle technology for nitride fuel*
- *Compatibility of structural materials with Pb alloy coolant*
- *Factory fabrication of transportable core or reactor module*
- *System application to hydrogen production*



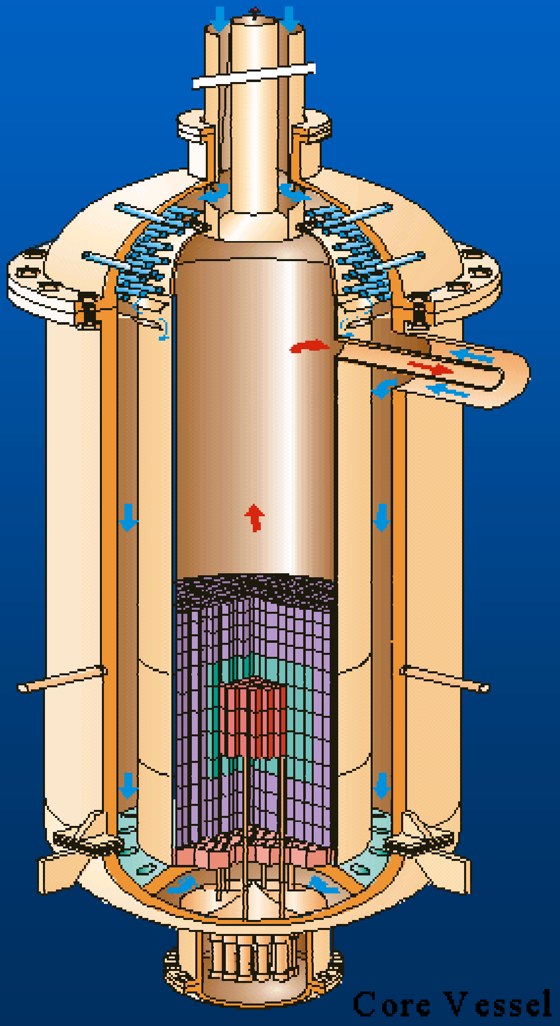
	Electricity	Hydrogen
Coolant	*Pb/Bi*	*Pb*
Coolant outlet temp.	*~550°C*	*~800°C*
Fuel	*Metal or nitride*	*Nitride*
Structural material	*Ferritic steel*	*Ceramic*

Pb/Bi Battery R&D

- *Development/verification of cladding and structural materials*
  - *Fabricability, compatibility with fuel and coolant, resistance to irradiation damage, retention of strength and ductility – over 15 to 20 year service life*
  - *Monitoring and control of coolant chemistry*
- *(U,TRU)nitride fuel and recycle development, building on existing programs in Japan and Europe*
- *Development of T/H data base for natural circulation heat removal*
- *Development of energy conversion technologies*
  - *Heat exchangers to transport heat to working fluid or hydrogen plant*
  - *Supercritical CO_2 turbine*
  - *Calcium-Bromine process for hydrogen production*

GFR: Technology Gaps

- ***Fuels with increased actinide and reduced moderator content relative to thermal spectrum systems***
- ***Efficient fuel recycle technologies***
- ***Materials for high temperature and high fast neutron fluence service***
- ***Safety concept to accommodate low thermal inertia and poor heat transfer capability of gas coolant at low pressure***

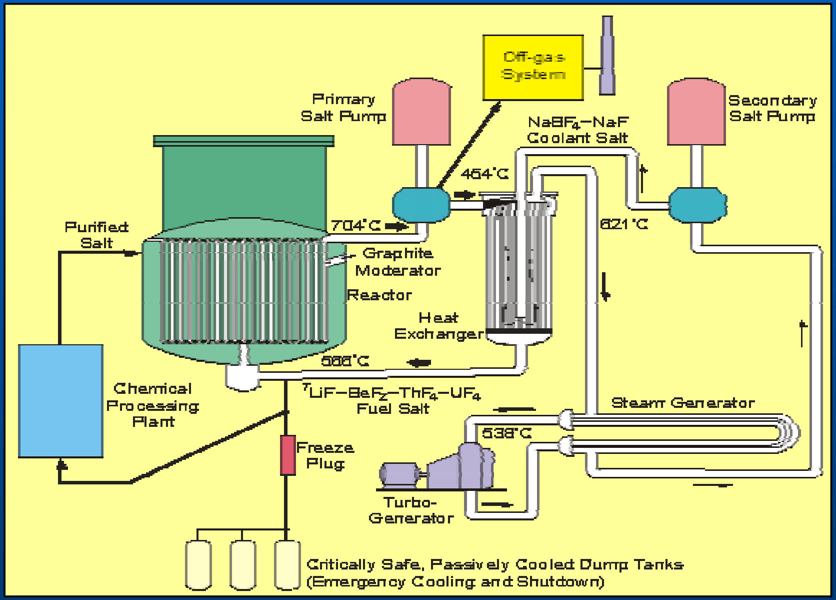


GFR R&D

- *Screening and evaluation of high actinide-density fuels*
  - *Modified coated particle or dispersion type fuels, e.g.,*
    - *(U,TRU)C/SiC*
    - *(U,TRU)N/TiN*
  - *Fuel pins with high-temperature cladding*
- *Core structural materials for high-temperature and fast fluence conditions (ceramics, composites, refractory alloys)*
- *Core configuration for enhanced thermal inertia and passive dissipation of decay heat*
- *Fuel recycle technologies*
  - *Separation of fuel compound from matrix*
  - *Aqueous and dry recycle options; ^{15}N recovery from nitride*

MSR: Technology Gaps

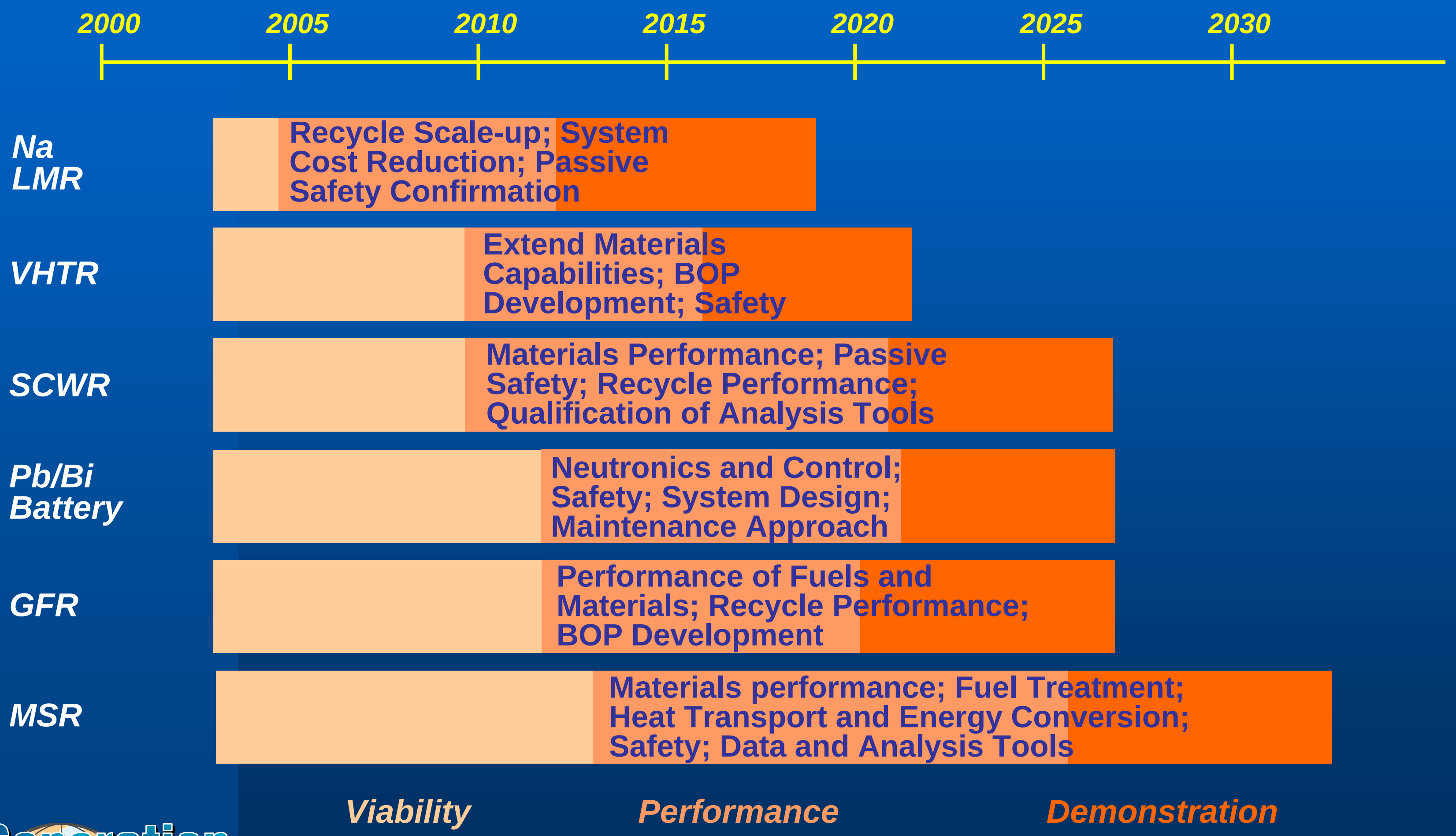
- ***Fuel salt selection and characterization***
  - ***Actinide consumption focus rather than efficient breeding***
- ***On-line fission product removal technology***
- ***Performance of metallic and graphite structural materials***
- ***System design for safety and reliability***



MSR R&D

- Selection/characterization of fuel salt for actinide consumption application
  - Limit generation of tritium
  - Verify solubility of minor actinides
  - Characterize behavior of fission and activation products
  - Determine thermo-physical data
- Develop processing technology for fuel salt leading to waste forms of acceptable purity and durability
- Demonstrate performance capabilities of metallic and graphite structural materials
  - Lifetime compatibility with molten salt constituents
  - Durability in radiation environment
- Develop technical means for resolving such challenges as
  - Preventing noble metal fission product plate-out on walls of the intermediate heat exchanger
  - Limiting tritium diffusion from primary system

Performance R&D Overview



Crosscutting R&D Approach

- Identify concept-independent technology gaps and advancement opportunities
- Examine concept specific R&D recommendations for applicability to multiple concepts
- Formulate concept-independent/common R&D
- Determine high-priority activities
  - Key to resolving viability issues or selecting among options
  - Significant opportunity for reducing R&D cost

Crosscut R&D Recommendations

Crosscut Area	Research Topic	Na LMR	Pb/Bi Battery	GFR	VHTR	SCWR	MSR
Fuel Cycle	Integrated once-through fuel cycle				X	X(T)	
	Optimum management of Cs and Sr	X	X	X		X(F)	X
	Cm management and target fabrication	X(O)	X	X		X(F)	
	Aqueous processing with group separation of Actinides	X(O)	X	X		X(F)	
	Pyroprocess actinide recovery optimization	X(M)	X	X			

M: Metal Fuel
O: Oxide Fuel

T: Thermal Spectrum
F: Fast Spectrum

Crosscut R&D Recommendations, cont'd

Crosscut Area	Research Topic	Na LMR	Pb/Bi Battery	GFR	VHTR	SCWR	MSR
Fuels and Materials	Properties and behavior of structural materials						
	T < 600°C	X	X			X	X
	600°C < T < 900°C		X	X		X	X
	900°C < T			X	X		
	Development of fuel fabrication techniques	X	X	X	X	X	
	Irradiation and transient testing campaigns	X	X	X	X	X	X
	Fundamental modeling of materials behavior	X	X	X	X	X	X
Energy Products	Analysis of market requirements		X		X		X
	Thermochemical water splitting processes		X	X	X		X

Crosscut R&D Recommendations, cont'd

Crosscut Area	Research Topic	Na LMR	Pb/Bi Battery	GFR	VHTR	SCWR	MSR
Economics	Modular fabrication and installation technologies	X	X	X	X		
	Instrumentation, control, and human-machine interface	X	X	X	X	X	X
Risk and Safety	Radionuclide transport and dose assessments	X	X	X	X	X	X
Evaluation Methods	Economics: consistent, integrated cost and revenue models	X	X	X	X	X	X
	Enhanced probabilistic risk assessment tools	X	X	X	X	X	X
	Proliferation resistance and physical protection criteria and methods	X	X	X	X	X	X

Next Steps

- Incorporate review comments on recommended R&D
  - Completeness
  - Justification/priorities
  - Designation as concept-specific vs. crosscutting tasks
- Integrate R&D recommendations and document in Roadmap R&D plan
  - RIT lead with support of WG leaders and key personnel
  - Delineate concept specific and crosscutting activities
  - Lay out major technology decision points
- Complete interim roadmap and issue for review